
Ultrasound in Emergency Medicine

BEDSIDE ULTRASOUND FOR THE DETECTION OF SOFT TISSUE FOREIGN BODIES: A CADAVERIC STUDY

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Abstract—The objective of this study was to evaluate the sensitivity and specificity of bedside ultrasound, as performed by emergency physicians with typical equipment, in detecting small, soft tissue foreign bodies, using a cadaveric model. This was a prospective study, using 6 unembalmed human cadavers and 6 ultrasound-credentialed, emergency medicine residency-trained physicians as sonographers. Incisions were made in 150 total sites of the extremities and each site was randomly assigned one of five groups: wood, metal, plastic, glass, or no foreign body. All foreign bodies were 2.5 mm³ in total volume or less, no longer than 5 mm in any dimension, and inserted to a depth of up to 3 cm. Ultrasound was performed with a SonoSite TITAN[®] (SonoSite, Inc., Bothell, WA) ultrasound system using a L38/10-5 broadband linear array transducer. Sonographers were blinded to the number, type, and location of foreign bodies. A total of 900 ultrasound examinations were recorded. Overall sensitivity of ultrasound for foreign body detection was 52.6% (95% confidence interval [CI] 48.9%–56.2%), and overall specificity was 47.2% (95% CI 39.9%–54.5%). Positive predictive value was 79.9% (95% CI 76.3%–83.5%), and negative predictive value was 20.0% (95% CI 16.2%–23.7%). Sensitivity for individual sonographers ranged from 40.8% to 72.3% (average 52.6% ± 13.3%), and specificity ranged from 30% to 66.7%

(average 47.2% ± 15.1%). Inter-observer reliability was poor. In our model, bedside ultrasound performed by emergency physicians was neither sensitive nor specific for the presence of small soft tissue foreign bodies. © 2009 Published by Elsevier Inc.

Keywords—ultrasound; foreign body; soft tissue; emergency medicine; musculoskeletal; cadaveric

INTRODUCTION

Ultrasound (US) has gained increasing favor in the Emergency Department (ED) over the past decade and has been employed in a myriad of clinical diagnostic and procedural applications (1). Multiple studies have been performed to determine the utility of US in excluding or identifying soft tissue foreign bodies (FB) (2–5). These studies achieved mixed results. Many physicians are using US as an adjunct to careful wound exploration and plain radiography for excluding soft tissue FB in appropriate settings. However, the reliability of ultrasound for this purpose is still the subject of debate. If ultrasound were demonstrated to be highly sensitive for the detection of foreign bodies, it could replace more expensive and time-consuming radiographic techniques such as computed tomography. It could also be used in out-of-hospital settings where other imaging techniques are impractical or unavailable.

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Our goal was to determine whether ultrasound examinations, done by emergency physicians (EPs) with standard equipment, are sensitive and specific for the detection of small soft tissue foreign bodies, the likes of which might be missed on physical examination of a traumatic wound. For our experimental model, we chose human cadaveric tissue as the medium, ultrasound equipment commonly used in EDs, and four types of small, radiopaque and radiolucent foreign bodies. To our knowledge, this is the largest study of its type to date. If proven reliable, ultrasound might be the method of choice to decrease the incidence of unidentified FB in wounds (4,6,7).

METHODS

Study Design

This was a prospective, cadaveric study. The study was approved by the Institutional Review Board of the sponsoring institution in an expedited review.

Study Setting and Population

The six sonographers in this study were all ultrasound-credentialed, EM residency-trained physicians, practicing at a 65,000-visits-per-year community hospital ED, where ultrasound is used widely for all typical EM applications. All physicians had attended a 2-day local ultrasound course given at the beginning of their tenure at the hospital, and had completed the minimum number of supervised examinations in each of the core EM-ultrasound categories, as delineated by the 2001 American College of Emergency Physicians policy for proficiency (8). Additionally, all had also attended at least one national EM ultrasound course. Although soft tissue ultrasound was taught in both ultrasound courses, and was actively practiced by these physicians in the ED, no specific number of prior soft tissue examinations was required for credentialing of these physicians or for participation in this study. Six unembalmed human cadavers were used as the tissue model.

Study Protocol

Incisions were made using a number 15 scalpel blade at a total of 150 extremity sites among the 6 cadavers: 18 left upper arm, 12 left forearm, 15 right upper arm, 10 right forearm, 30 left thigh, 18 left calf, 29 right thigh, and 18 right calf. Each site was then randomly assigned one of five categories: wood, metal, plastic, glass, or no

foreign body. A total of 30 sites were designated for each of these groups. Foreign bodies were inserted into the incision, using hemostats, to depths up to 3 cm. All FBs were 2.50 mm³ in total volume or less, and were no longer than 5 mm in any dimension. Ultrasound examinations were done with a SonoSite TITAN[®] ultrasound machine and a L38/10-5 broadband linear array transducer (SonoSite, Inc., Bothell, WA) set to "resolution" mode (up to 10 mHz). Sonographers were blinded to the overall number, type, and location of the foreign bodies. Each was shown a known positive and negative foreign body site, and then was told to scan each of the 150 experimental sites in two planes, without the use of a step-off pad, and state whether a foreign body was present or not. All decisions by sonographers were made in real time, and no images were retained for subsequent review. Physicians were encouraged to scan as they usually would clinically, and were allowed to manipulate the controls of the ultrasound machine as desired to optimize their views. Data were recorded on standardized data collection sheets.

Data Analysis

Sensitivity, specificity, positive and negative predictive values, and likelihood ratios were calculated for each sonographer's set of examinations, and for the group as a whole. The sensitivity of ultrasound for each type of foreign body, and sensitivity and specificity of ultrasound at each anatomical site were calculated. Inter-observer reliability was assessed by average kappa statistic, computed over all pairs of observers. Confidence intervals were determined using the Wald Equation. All computations were done using Microsoft Office Excel 2003-SP2 software (Microsoft Corporation, Redmond, WA).

RESULTS

A total of 900 ultrasound examinations were recorded. The overall sensitivity of ultrasound for detection of a foreign body was 52.6% (95% confidence interval [CI] 48.9%–56.2%), and overall specificity was 47.2% (95% CI 39.9%–54.5%). The positive predictive value was 79.9% (95% CI 76.3%–83.5%), and the negative predictive value was 20.0% (95% CI 16.2%–23.7%). Positive and negative likelihood ratios were 1.00 (95% CI 0.81–1.24) and 1.00 (95% CI 1.28–0.80), respectively. Sensitivity for the individual sonographers ranged from 40.8% to 72.3% (average 52.6% ± 13.3%), and specificity ranged from 30% to 66.7% (average 47.2% ± 15.1%). For all observer pairs, average kappa was 0.140

Table 1. Test Characteristics by Sonographer, Foreign Body Location, and Foreign Body Type

	Sensitivity	Specificity	LR+	LR-
Sonographers				
#1	72.3% (64.2–80.3%)	30.0% (21.8–38.2%)	1.03 (0.82–1.30)	0.92 (1.64–0.51)
#2	66.7% (58.2–75.1%)	30.0% (21.8–38.2%)	0.95 (0.74–1.22)	1.11 (1.92–0.65)
#3	45.0% (36.0–53.9%)	66.7% (58.2–75.1%)	1.35 (0.86–2.16)	0.83 (1.10–0.61)
#4	40.8% (32.0–49.6%)	60% (51.2–68.8%)	1.02 (0.66–1.59)	0.99 (1.33–0.73)
#5	46.7% (37.7–55.6%)	50.0% (41.1–58.9%)	0.93 (0.64–1.35)	1.07 (1.52–0.75)
#6	44.2% (35.3–53.1%)	46.7% (37.7–55.6%)	0.83 (0.57–1.19)	1.20 (1.71–0.84)
Anatomical location				
Thigh	59.6% (53.8–65.5%)	40% (29.9–50.1%)	0.99 (0.77–1.31)	1.01 (1.55–0.69)
Calf	58.1% (51.0–65.2%)	43.3% (25.6–61.1%)	1.02 (0.69–1.67)	0.97 (1.92–0.57)
Forearm	46.0% (36.8–55.2%)	61.1% (38.6–83.6%)	1.18 (0.60–3.37)	0.88 (1.64–0.54)
Upper arm	38% (30.2–45.8%)	59.5% (44.7–74.4%)	0.94 (0.55–1.79)	1.04 (1.56–0.73)
Foreign body type				
Glass	52.2% (44.9–59.5%)			
Metal	48.6% (41.3–55.9%)			
Plastic	53.9% (46.6–61.2%)			
Wood	55.6% (48.3–62.8%)			
None	52.8% (45.5–60.1%)			

(95% CI 0.126–0.155). The test characteristics for each sonographer, FB type, and anatomical location are presented in Table 1.

DISCUSSION

Some previous studies demonstrated high sensitivity and specificity of ultrasound for detection of FB in soft tissue; three have shown overall sensitivities > 89% and overall specificities > 93% (2,3,5). Similarly to these studies, our study employed a cadaveric model, utilized comparable transducers, and used multiple sites in the same model. However, procedural differences in our study included the training of the sonographers, their primary practice specialty, type of cadaveric model, location of foreign body, placement of foreign body, and brand of ultrasound equipment. In contrast to these prior studies, we found poor sensitivities and specificities for all foreign body types studied. Hill et al. similarly showed that in the hands of “relatively inexperienced” emergency physicians, ultrasonographic evaluation of soft tissue injury is neither sensitive nor specific enough for use alone to determine the presence or absence of a foreign body (4). This highlights one of the differences between the studies that portray US as more useful in this arena and those who suggest otherwise—the level of training and experience of the sonographers. Two of the three studies that indicated US was of benefit utilized physicians who primarily read radiographic studies, whereas the third did not mention who performed the scan (2,3,5). Our study utilized EPs who had limited additional formal and on-the-job training. Although it stands to reason that a physician primarily trained in imaging might make a more sensitive and specific ob-

server, we felt it would be more appropriate to design an experiment around the physicians who, in our ED and many like it, are the primary users of US for this purpose.

Other factors potentially responsible for the poor performance of ultrasound in our study include the placement of the FB, and the nature of the tissue model used. Two of the studies where ultrasound performed better utilized hands and feet only, and tissues that were either “freshly amputated” or “fresh frozen,” whereas our study and that by Hill et al. both utilized extremity sites other than hands and feet (3–5). Our study utilized whole body cadavers that were unembalmed and not necessarily as “fresh” as the recently amputated counterparts in the other studies. Difficulties inherent to our cadaveric model include distortions of soft tissues that uncontrollably occur post-mortem, including sloughing of the superficial layers of skin and dehydration of tissues. This model was chosen from several potential models for studying this question, to include animal tissue, phantoms, and human patients, each with its own strengths and weaknesses. This one was selected to reasonably simulate human tissue, while maximizing sample size, and providing several different soft tissue environments and depths. Also, the FBs in our study were placed as deep as 3 cm, whereas two of the studies that found better sensitivities utilized depths of 1 cm or less. We intentionally chose very small foreign bodies, to replicate conditions that occur with many traumatic wounds, and to specifically target FBs that are more likely to be missed clinically. The FB size we chose may have been smaller than the resolving power of our instrument in one or two of the three dimensions. Thus, the spatial orientation of some FBs may have made them more difficult to detect, though this may be clinically realistic. No

specific orientation of the FBs in the tissue was prescribed in our protocol.

Likewise, another factor that could be responsible for the large discrepancy between these studies is our use of a bedside ultrasound instrument rather than a more sophisticated ultrasound machine, like those used in radiology ultrasound suites. Although we used an ultrasound instrument that is widely used in EDs, the difference in image quality between machines can be considerable, and could potentially contribute to the marked differences in study results. We chose this instrument as we felt it would best represent the characteristics of a bedside ED test, rather than a formal examination done in a dedicated ultrasound suite.

LIMITATIONS

There are several limitations of our methodology. As soft tissue ultrasound by EPs is a relatively new consideration, the training these physicians received may not have included an appropriate depth of instruction in evaluating soft tissue. Our model, like any experimental model, may not have optimally represented live human tissue, and we may have portrayed US in an excessively negative light due to any of the parts of our model, as described above. Neglecting the above, our findings may still not generalize to the clinical arena, as we used US as a test in isolation, whereas in clinical practice, it is

generally used in concert with physical examination and radiography.

CONCLUSIONS

In our cadaveric model, bedside US by EPs without intensive training, and using standard equipment, seems to be neither sensitive nor specific for the detection of small soft tissue foreign bodies. Within the limitations of our study, our findings may contradict some previous results. Further study is indicated.

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